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Malaria

The Impact of Treated Bed-Nets on Childhood Mortality in the Gambia

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In rural Gambia, as in many parts of Sub-Saharan Africa, malaria remains a major cause of death for children below the age of five — indeed, the principal cause of death when vaccination coverage rates are high and death rates from common infectious diseases of childhood are reduced. In recent years, concern has grown about the development of drug-resistant strains of malaria — provoking renewed interest in vector control and the reduction of man-vector transmission rates.

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This paper — a product of the Population, Health, and Nutrition Division, Population and Human Resources Department — emanated from the Bank's support of Johns Hopkins University for a child survival workshop focused on PHR's Health Sector Priorities Review. Copies of the paper are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact Otilia Nadora, room S6-065, extension 31091 (April 1992, 30 pages).

The effectiveness of insecticide-treated materials had been unclear, as earlier studies had based their results on the effects on vectors rather than on human morbidity and mortality rates from malaria. So in 1988 the UK Medical Research Council began a systematic trial of a combined intervention for controlling malaria around the small town of Farafenni, in central Gambia. Two interventions — bed-nets treated with Permethrin and chemoprophylaxis with Maloprim (dapsone = pyrimethamine) — were conducted in "primary-health-care" villages, with non-PHC villages serving as controls.

The study showed that general and malaria-specific mortality in young children was sharply reduced by introducing Permethrin-treated bed-nets. The effects of using treated bed-nets were clear, because many children had been sleeping in bed-nets before the intervention began without the same strong effects.

The treated bed-net intervention had the additional effect of reducing other causes of death. This "frailty protection" effect was substantial but is largely unexplained — more basic research is needed.

Also, not all children have to be sleeping in bed-nets for the benefits of the treatment to be felt. Small rates of noncompliance need not invalidate the effectiveness of the intervention.

The nets were dipped by village women, supervised by the village health worker and the traditional birth attendant, with the support of the women's association. It appears that the washing and dipping process can be undertaken successfully by local people with a minimum of supervision, at a cost for the solution of a few US cents per net dipped.

The extra reduction in mortality attributable to the use of Maloprim as a prophylactic was probably slight and difficult to detect in this study because of the strong effect of sleeping under a treated bed-net.

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MALARIA: THE IMPACT OF TREATED BED-NETS ON CHILDHOOD MORTALITY IN THE GAMBIA

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In rural Gambia, as in many other parts of sub-Saharan Africa, malaria remains one of the most important causes of death in children under five. [1] When vaccination coverage rates are high and deaths due to the common infectious diseases of childhood are reduced, malaria may be the principal cause of death. [2] Malaria is particularly important to control not only because of its direct effect on mortality and morbidity but also because it acts in conjunction with other diseases to increase both morbidity and mortality rates from other causes. [3]

THE STUDY

In recent years, there has been growing concern about the development of drug-resistant strains of malaria, provoking renewed interest in vector control and the reduction of man-vector transmission rates. [4] The efficacy of insecticide-

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[1] BM Greenwood, AK Bradley AM Greenwood et al. Mortality and morbidity from malaria in a rural area of The Gambia, **Trans R Soc Trop Med Hyg** 1987 81:478-86. U and A Brinkmann, Malaria and health in Africa: present situation and epidemiological trends, **Trop Med & Parasitol** 1991, 42:204-13.

[2] BM Greenwood, AM Greenwood, AK Bradley et al. Deaths in infancy and early childhood in a well-vaccinated, rural West African population. **Ann Trop Paediat** 1987 7:91-9.

[3] DCW Mabey, A Brown, BM Greenwood. Plasmodium falciparum malaria and Salmonella infections in Gambian children. **J Infect Dis** 1987 46:181-202.

[4] JA Rozendaal. Impregnated mosquito nets and curtains for self-protection and vector control. **Trop Dis Bull** 1989 86:R1-R41; CF Curtis, JD Lines, P Carnevale et al. Impregnated bed nets and curtains against malaria mosquitoes. In: **Appropriate methods**

treated materials has been unclear since previous studies have based their results on the effects on the vectors rather than on the malaria morbidity and mortality rates in the human population. In 1988, therefore, the UK Medical Research Council began a systematic trial of a combined intervention for the control of malaria in central Gambia around the small town of Farafenni. On the North Bank, some earlier work had suggested that chemoprophylaxis with Maloprim (dapsone + pyrimethamine) and Permethrin-treated bed-nets had reduced malaria morbidity but the intervention was too small scale for much to be said about mortality. [5] For the new double-intervention trial with permethrin-treated bed-nets and Maloprim used in combination, a new site was chosen south the Gambia river and east of Farafenni town. The area included 73 villages in all, of which 17 of the larger villages, generally those with 400 or more people, had joined the government's Primary Health Care scheme. The 56 smaller villages are here referred to collectively as 'non-PHC' villages. Both the interventions, the treated bed-nets plus the chemoprophylaxis, were conducted in the PHC villages with the non-PHC villages serving as controls (see Table 1).

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of vector control, ed. CF Curtis, CRC Press, Florida, 1990:5-46; WHO. The use of impregnated bednets and other materials for vector-borne disease control. (WHO/VBC 89.981). WHO, Geneva, 1987. For a recent general review, see SC Oaks et al, 1991, **Malaria: obstacles and opportunities**, Institute of Medicine, US National Academy Press.

[5] RW Snow, SW Lindsay, RJ Hayes, BM Greenwood. Permethrin-treated bed-nets (mosquito nets) prevent malaria in Gambian children. **Trans R Soc Trop Med Hyg** 1988: 82:838-42.

Table 1: Summary of activities in the PHC and non-PHC villages

Period	PHC treatment villages (17 villages: children= 2616)		Non-PHC controls (56 villages: children= 1795)
PRE-INTERVENTION PERIOD			
June 1988 to July 1989	Census followed by routine collection of data on births, deaths and migration with verbal autopsy questionnaires for all children dying under age 6		
INTERVENTION PERIOD			
July 1989 to June 1990	Treated bed-nets plus 1/4 strength Maloprim for half of all children 6 months to 5 years	Treated bed-nets and placebo for the other half of all children 6 months to 5 years	Mortality and morbidity surveillance only
POST-INTERVENTION PERIOD			
May-June 1990	New census with up-dating of all records of births and deaths plus a single round retrospective demographic survey with a full birth history for all women of reproductive age. Verbal autopsy analysis.		

The total population of all the villages averaged 21,157 individuals, comprising mostly Mandinka-speakers with some Fula as well as other smaller ethnic groups. In this area of flat Sudan savanna, with mangrove swamps at the river's edge, the rainfall is close to 1000 mm. per year: in 1988, it was 1051 mm and in 1989 it was 887 mm. The rainy season from June to October is the most important season for the transmission of malaria by the Anopheles gambiae complex and most malaria deaths are concentrated in September, October and November of each year. In this paper, only the effects of interventions on the mortality of young children are discussed. Full details of the conduct of the intervention, the dipping of the bed-nets and the

chemoprophylaxis is available elsewhere. [6] The effects of the bed-nets on the incidence of clinical malaria and the prevalence of malaria infection will be reported separately. [7]

The interventions in the PHC villages

In July 1989, all bed-nets in the PHC villages were first washed and then dipped in a Permethrin solution designed to produce a dose of about 500mg per m^2 of net. Altogether, 5380 bed-nets were treated in this way, 88% of all nets in use in the villages. In all, 92% of all children in the PHC villages slept in treated bed-nets during the intervention trial. Before the intervention began, it should be noted, 96% of children in the PHC villages had been sleeping in untreated bed-nets. Even in the non-PHC villages, 77% of children had been sleeping in untreated bed-nets. Then, all children in the PHC villages in the target age group, 6 months to five years, were randomized into two groups for receipt of either 1/4 strength Maloprim (25mg dapsone + 3.13 mg pyrimethamine) or a placebo of similar colour and taste. Chemoprophylaxis was continued for 20 weeks, July to November 1989, the main period of malaria transmission. Detailed compliance records were kept and random urine tests were conducted for the presence of dapsone. Compliance in the treatment and placebo groups was the same (95%) and more than 75% of the children in the treatment and control groups took their tablets on 90% of the required occasions.

Mortality surveillance

Once the study area had been identified, a full census of the 73 villages was carried out, listing all usual residents of

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[6] P Alonso, SW Lindsay, JRM Armstrong, M Conteh, AG Hill, PH David, G Fegan, A de Francisco, AJ Hall FC Shenton, K Cham, BM Greenwood. Reduction of mortality in Gambian children by insecticide-treated bed-nets. **Lancet** 337: 1499-1502, 22 June 1991.

[7] Alonso et al, forthcoming.

each compound and family by name, age and sex. From 1 July 1988, village reporters recorded all births, deaths and permanent migration movements occurring in their villages. This information was collected weekly and checked by MRC field assistants, men and women with secondary school education from the area or nearby. At the MRC field station near Farafenni, these data were regularly entered into a computer so that updated census files could be maintained and checked on a continuous basis.

In addition, a single-round retrospective survey of the lifetime fertility and childhood mortality experience of all women of reproductive age in the study area was carried out early in 1990 for two reasons. First, information on the longer-term trends in childhood mortality were needed to be sure that childhood mortality had not been on diverging paths in the pre-intervention period in the PHC and non-PHC villages. There were some concerns that mortality might have been changing at a different rate in the larger PHC villages compared with the non-PHC villages. In addition, despite the care and attention which goes into the routine recording of vital events in the surveillance area, there are always a few events which slip through the net. Some of these can be picked up during the annual dry season re-enumeration of the population. Accordingly, a household form including the basic Brass questions on children ever-borne alive and surviving to interview was designed, as well as a simple birth history for all women of reproductive age, regardless of marital status. The childhood deaths from the birth histories were then matched with the MRC records to ensure completeness of coverage. Only a small number of discrepancies were found, largely due to errors in the retrospective dating of vital events in the single-round survey.

Cause of death ascertainment

All the parents or guardians of children who died in the study period (1 July 1988 until 30 June 1990) in both PHC and

non-PHC villages were interviewed by a senior field assistant using a special questionnaire developed initially on the North Bank and at Bassé for the ascertainment of the likely cause of death. This form was then examined independently by three physicians familiar with the area and with the symptoms of the main causes of death in the area. Each then decided on the principal cause of death using whatever information was on the form or on attachments to it. These attachments often included the child health card, sometimes a record of treatment for a prior illness, and occasionally a report from a clinic or a hospital if the child had been taken there before death. In 43.4% of the 318 valid cases, all three physicians agreed on the main cause of death for the children of all ages who had died during the period of the intervention. In 93.4% of all valid cases, two of the physicians were in agreement. On four main causes, acute respiratory infections, diarrhoea/malnutrition, acute gastro-enteritis and tetanus, the agreement between the three physicians was over 50 per cent. For malaria, they agreed in 44% of cases. It turned out that the most difficult cases were neonates or children under six months; in almost a third of the cases of deaths under six months, a final cause of death could not be determined. Recognizing these difficulties and indeed the problems of post-mortem cause of death ascertainment without a hospital autopsy, the three physicians then conferred with all the evidence before them. Overall, a final diagnosis was agreed upon for 73% of the cases, 66% for children who died at 6 months of age or older. It is this final diagnosis agreed between the three physicians which is used here.

RESULTS

Childhood mortality

The routinely collected surveillance data can be used quite readily to estimate childhood mortality for the two years, before and after the interventions. The only difficult feature is the estimation of the denominators, the children at risk, since there

is considerable movement in the area and it is impossible to keep track of all short-term migration. In view of the seasonal nature of many of these movements, it was decided to estimate the mid-period population by taking the average number of children present in the area. The end of period populations had been updated to take account of losses or omissions picked up in the annual re-enumeration of the population. These results from period life table calculations are summarized in Table 2.

Table 2: Childhood mortality for PHC and non-PHC villages south of Farafenni before and after the introduction of bed-nets

	Primary Health Care villages			Non-Primary Health care villages		
	IMR	$_4q_1$	$_5q_0$	IMR	$_4q_1$	$_5q_0$
1988-89	0.110	0.157	0.249	0.093	0.100	0.184
Deaths	59	75	134	35	32	67
1989-90	0.072	0.045	0.114	0.116	0.103	0.207
Deaths	41	25	66	43	35	78

Note: The separation factors for the calculation of the probabilities of surviving or dying were taken from the data, since in almost all cases, dates of birth and death were known in the form of day, month and year. IMR = infant mortality rate.

The data in Table 2 have several interesting features. One is the level of childhood mortality indicated. Although we have come to expect values of around 100 per thousand for infant mortality, it is a surprise to see that this value is still the figure in The Gambia where there has been a good Primary Health Care system since 1983 and where immunization coverage is remarkably high. Each year from 1985 onwards, The Gambian government has carried out an EPI survey around December-January with the results shown in Table 3. The figures for the whole country in 1989 and 1990 are very impressive, especially so since

the coverage in the Central and Eastern regions was as high as in the Western region around Banjul. The mortality figures have to be interpreted in the context of this high immunization coverage, since some common causes of childhood mortality in West Africa, such as measles and tetanus, are almost absent from the cause of death data from Farafenni.

A second interesting feature of the mortality data by age is the high rates for the age group 1-4 relative to the infant mortality rates. It was once thought that one explanation for the high later childhood mortality in West Africa might be measles but this is clearly not the case since measles mortality has been drastically reduced by the immunization programme. Another factor must be responsible for the high ratio of the of mortality of 1-4 year-olds to the mortality of infants. These dramatic reductions in mortality of the 1-4 age group were not matched in the non-PHC villages for the same period. Some fall in infant mortality was recorded in the PHC villages. This seems surprising but there is good evidence that more infant deaths than previously thought are related to malaria in this area. In addition, there appear to have been some complex interactions between malaria and other illness which complicate the identification of the effect of the bed-net intervention.

Table 3: National immunization coverage rates estimated from the annual EPI coverage surveys (percentages)

Antigen	1985	1986	1987	1989	1990
BCG	92	97	90	98	98
DPT (3)	68	72	77	83	87
Polio (3)	62	69	83	89	92
Measles	75	80	82	81	85
Yellow fever	70	73	81	87	85
Fully immunized	52	[illegible]	61	70	78

To look further back in time at trends in childhood mortality in the two different sets of villages before the intervention began, mortality rates were calculated from the birth histories obtained from women of reproductive age in January-February 1990. In addition, it was possible to go back to the data tapes from the 1983 national population census and to produce tables of the proportions dead of children ever-borne alive by age of mother for exactly the same villages included in the intervention trial. The data from the birth histories are more reliable since it was possible to re-check some results with reference to the MRC surveillance data. The level and trends in under 5 mortality are shown on Figure 1. Much the same results are obtained from the indirect estimates from the 1983 census but omission of children ever-born as well as dead children by comparison with the surveillance data make these results difficult to interpret. The data on Figure 1 strongly suggest that whilst there had been a slow improvement in child mortality before the intervention, the mortality in the two sets of villages chosen for the intervention was not very different despite the different sizes and different participation in the national primary health care system by the two types of villages. A clear demonstration of the role of malaria in the mortality decline can be seen in the graph of deaths by month for PHC and non-PHC villages (see footnote 6).

THE IMPACT OF THE BED-NETS

General mortality

The data in Table 4 show that the probability of dying for 1-4 years olds fell sharply in 1989-90 to 29% of the 1988-89 level in the PHC villages. Mortality in this age range was unchanged in the non-PHC villages. These results can be expressed in a more detailed way using the rate ratios of the age-specific death rates from the life tables (Table 4).

Table 4: Age-specific death rates and rate ratios before and after the intervention.

PRE-INTERVENTION			
Age	PHC villages	Non-PHC villages	Ratios
0	115.9 (59/509)	99.1 (35/353)	1.169
1-4	44.5 (75/1685)	27.7 (32/1156.5)	1.609
POST-INTERVENTION			
0	75.2 (41/545.5)	135.2 (43/318)	0.556
1-4	11.8 (21/1775)	28.4 (35/1232)	0.416

The effect of the bed-nets on the mortality of the 1-4 year olds is particularly clear although the decline in infant mortality is also significant. There is no obvious explanation for the higher initial levels of 1-4 year old mortality in the PHC compared to the non-PHC villages in the pre-intervention period. There is a suggestion in the cause of death data from the two sets of villages that malaria and severe diarrhoea/malnutrition with gastro-enteritis may be more important causes in the larger PHC villages. Whatever the reasons for the initial differences, the bed-net intervention has reversed this relationship between the mortality in the two sets of villages. Although some of the numbers are very small, examination of the rate ratios for single years of age reveals that the decline in mortality in the PHC villages was especially marked for one year old children. In the PHC villages, deaths in this age category fell from 35 to 8 over the two years; for the non-PHC villages, the number of deaths of one year olds rose from 14 to 18.

The results from the morbidity surveillance, including measurement of body temperatures and blood slides for those with fever, and the studies of the mosquito populations, will show that these mortality results are directly associated with a

proportionate reduction in cases of mild and severe clinical malaria and in overall transmission rates (Alonso et al, forthcoming).

Cause-specific mortality

Although the intervention was directed at children aged 6 months to 6 years, this section will examine the mortality of all children under 6. We have retained the data on the younger children both to keep the numbers as large as possible and because we have good evidence that the intervention had a substantial and surprising impact on childhood mortality in general (Table 4). In addition, by working with all the under fives we can more easily make comparisons with life table measures of childhood mortality from other populations.

The main causes of death for all children dying before and after the intervention are shown in Figure 2. The 'don't know' category includes both those deaths for which the three physicians could not agree and those deaths where no single cause could be identified by any of the physicians reading the post-mortem questionnaires. Before the intervention, in both the PHC and the non-PHC villages, malaria was thought to be the main cause of death in 28% of all deaths. If we exclude the deaths of those under 6 months, malaria deaths constituted 39% of all deaths in the pre-intervention year taking both PHC and non-PHC villages together.

Turning to changes in cause-specific mortality by treatment group, we see from Figure 3 the relatively small changes recorded in the non-PHC villages. There were some changes in the numbers dying of acute respiratory infections, meningitis, acute gastro-enteritis and septicaemia but the most notable feature of Figure 3 is the relatively small change in the number of malaria deaths. Figure 4 presents the mortality data on cause of death for the PHC villages. The sudden fall in deaths due to malaria is obvious. The reduction in the numbers of malaria deaths in the PHC villages was not made up by increases in other categories.

On the contrary, it seems that the bed-nets intervention had an effect on some other significant causes of death, deaths attributed to acute respiratory infections in particular. There are problems in looking at these changes in specific causes both because of the uncertainty which surrounds the post-mortem cause of death assignment and because of small numbers. In an attempt to examine some of these changes in a relatively simple way, the ratio of the numbers of deaths in the pre- and the post-intervention periods have been calculated for PHC and non-PHC villages separately. Overall, the ratio of all deaths of children under age 5 in PHC and non-PHC villages was 1.77 (158/89) largely because of differences in the size of the two study populations. Figure 5 shows these ratios as well as the average for all the causes combined. Taking into account the small numbers in some categories (see Appendix 1 for the basic data), there are some remarkable reductions in the ratios for the acute respiratory infections and the diarrhoea/malnutrition categories between the pre- and post-intervention periods. The change in deaths due to the acute respiratory infections is especially significant because of the number of deaths due to this cause (in the pre-intervention period, 38 under fives died of this cause in the PHC and non-PHC villages combined).

The effects of the Maloprim administered to half the children in the PHC villages were swamped by the more powerful effects of the treated bed-nets. There were only 11 deaths, 2 attributable to malaria, in the Maloprim group and 10 in the placebo group, 6 attributable to malaria.

Although not detectable in the mortality data, the data on morbidity shows that even for those children not sleeping in treated bed-nets, there were reductions in the frequency of fevers and of positive blood slides. This observation points to the possibility of a more general community effect which may be very important when compliance rates for the intervention are lower than in this study. The effects on the mosquitoes are thought to operate both through the insecticide and through the

emulsion in which the insecticide is dissolved. Different emulsions may have different effects in deterring mosquitoes from even entering the sleeping areas. Work continues on this problem and on the development of waterproof emulsions which can resist washing.

It should be noted that in both the PHC and the non-PHC villages, weekly blood slides were made for all children with a temperature of over 37.5°. Those with parasitaemia were referred to the Village Health Worker for treatment. Field workers were asked to follow up on these children and to arrange further treatment outside the village if necessary.

Theoretical explanation

The results indicate a strong direct effect of the treated bed-nets in an area where the use of bed-nets was well established before the intervention began. If such high levels of compliance can be achieved nationally, major reductions in both malaria-specific and overall childhood mortality can be anticipated. The effects described here are clearly much larger than can be anticipated in the national programme but the trial has brought to light some new aspects of the disease. One is the proportional reduction in the numbers of infected bites, in mild and severe cases of malaria as well as in malaria-related deaths. [8] Some mild cases still became severe cases but the additional effect of the Maloprim was to reduce the numbers of severe cases as well as deaths. The bed-nets and chemo-prophylaxis therefore have different effects on the demography of malaria since Maloprim is effective on just one part of the continuum from infected bite to malaria death whereas the effects of bed-nets were seen at every level in this transition. It seems that the reduction in malaria mortality is due to reduction in biting

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[8] See BM Greenwood, K Marsh and RW Snow, Why do some African children die of severe malaria? **Parasitol Today** 17(10): 277-81.

rates by mosquitoes and is not due to the reduction in other insect-borne diseases such as sleeping sickness and kala azar which in The Gambia are now quite rare. There is a possibility that elimination of some flies might have reduced enteric infections but the reduction in acute respiratory infections is greater than the reductions in the diarrhoeas and the severe gastro-enteritic infections.

The 'frailty protection' effect resulting from the avoidance of malarial infections is more difficult to explain. As with measles infections, there may be considerable and lasting gains to be had from the avoidance of infection by the malarial parasite and avoidance of the consequences of this infection such as anaemia.

The demographic impact of the bed-nets

There are a variety of ways of estimating what might be referred to as the 'gross' and 'net' effects of the bed-net intervention on childhood mortality. Here we compare the mortality outcomes we might anticipate by re-analyzing the life tables constructed from the surveillance data using the new information on cause of death. Three different comparisons are made. One is to compare the mortality before the intervention with the mortality which would ensue if all the deaths whose main cause was judged to be malaria were eliminated. A second comparison is between this mortality in the absence of malaria with the observed mortality rates in the post-intervention period in the PHC villages. Finally, we can check our calculations by comparing these results with the data from the non-PHC villages.

Table 5 contains the basic data for these comparisons. Using the data from the PHC villages first, we can see that the elimination of all malaria deaths would reduce infant mortality to 83% of its pre-intervention levels but the reduction in the mortality of 1-4 year-olds would be much greater: 56% of pre-intervention levels. Moving to the last line of the table to consider the same comparison for the non-PHC villages, similar

figures are obtained. Overall, the elimination of all deaths believed to be directly due to malaria would reduce the probability of dying before age 5 to about 70% of pre-intervention levels.

Table 5: Comparison of changes in childhood mortality following the elimination of malaria deaths and the use of bed-nets

PHC VILLAGES			
	IMR	${}_4q_1$	${}_5q_0$
With malaria	109.6	156.7	249.1
No malaria	91.0	88.4	171.3
Bed-nets	72.4	44.6	113.8
Ratios			
No malaria/malaria	0.83	0.56	0.69
Bed-nets/malaria	0.66	0.28	0.46
NON-PHC VILLAGES			
1988-9 with malaria	93.0	100.3	184.0
1989-90 with malaria	116.1	102.9	207.0
Mean 1988-90	104.5	101.6	195.5
No malaria (2 yr average)	102.2	66.0	161.4
Ratios			
No malaria/malaria 1988-90	0.98	0.65	0.74

Much more exciting is the comparison between the pre-intervention levels and the actual mortality outcomes as measured in the post-intervention year. As we see from the middle section of Table 5, the mortality of the 1-4 year olds was cut to 28% of pre-intervention levels and the probability of dying before age 5 fell to 46% of its pre-intervention level. Quite clearly, the

prevention of malaria has had a powerful synergistic effect on some other causes of death such as acute respiratory infections. In The Gambia, the case for this effect is stronger than it might be elsewhere in Africa because some possibly confounding causes of deaths (measles in particular) have already been controlled by the time of the intervention. We refer to the effective immunization programme which makes it unlikely that the reductions in childhood mortality can be simply explained by the temporary absence of some other epidemic causes of death such as whooping cough or measles. Certainly, no exceptional outbreaks of other causes of death such as meningitis were recorded during the intervention trial.

Conclusion

This study has shown that general and malaria-specific mortality in children under 5 have both been sharply reduced by the introduction of Permethrin-treated bed-nets. The extra reduction in mortality provided by the use of Maloprim taken as a prophylactic was probably slight and difficult to detect in this study because of the very strong effect of sleeping in a treated bed-net (see footnote 6). Work not discussed in detail here shows that both the mosquito population and malaria morbidity were both reduced by the intervention. The effects of the treatment of the bed-nets with Permethrin reported here are clearly due to the treatment and not just to the use of bed-nets since a large proportion of children had been sleeping in bed-nets before the intervention began.

There are two additional findings of importance to those interested in malaria-eradication programmes. One is the clear additional effect on other causes of death of the treated bed net intervention. This 'frailty protection' effect is substantial but largely unexplained. More basic research is this area is called for.

A second finding is that not all children have to be sleeping in bed-nets for the benefits of the treatment to be felt. If the community as a whole participates in the intervention, some small rates of non-compliance need not invalidate the effectiveness of the intervention.

It must be remembered that the dipping of the nets was carried out entirely by village women under the supervision of the Village Health Worker and the Traditional Birth Attendant with the support of the women's association. No major difficulties were encountered during this process although several women did wash their nets in the middle of the intervention, thereby diluting the effects of the insecticide. The experience in the Farafenni area leads us to believe that the washing and dipping process, including making up the solution with the correct concentration, can be undertaken successfully with the minimum of supervision in other contexts. The costs of the solution are a few US cents per net dipped.

There are no signs that the intervention has produced any toxicity or other adverse reactions; the chemicals are difficult to detect two weeks after the dipping has taken place. [9] There are some unanswered questions about the implications of the loss of immunity whilst protected from mild infection when using a bed-net, and the effects of the bed-nets on adult mortality and morbidity have not so far been studied in detail. Mosquitos will soon develop some resistance to Permethrin but by altering the type of insecticide used every few years, it should be possible to keep ahead of these changes. Other behavioural adaptations of mosquitos denied easy access to human blood are difficult to predict. There are some indications that adults in the intervention villages received additional bites. If the

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[9] RW Snow, M Jawara, CF Curtis **Bull Ent Res** 1987 77:279-86; RW Snow, SW Lindsay, RJ Hayes, BM Greenwood **Trans R Soc Trop Med** 1988.

mosquitos were to move to animal hosts, the cycle of malaria transmission would be broken.

For estimating the mortality effect of the use of treated bed-nets elsewhere, it may be worth remembering one or two distinctive characteristics of malaria in The Gambia. One is the highly seasonal nature of transmission; we have no evidence of the results will be the same in populations in which malaria is present all year round. Secondly, the Anopheles gambiensis does not bite during the day whereas other species have different biting habits. Thirdly, the high level of immunization achieved in The Gambia may make the effects of malaria control on mortality clearer than elsewhere since the number of competing risks from other infectious diseases has been limited. Finally the form of living arrangements of the Mandinka, large families living in crowded compounds with wives, co-wives and children sharing a common sleeping room, may be responsible for some of the especially strong effects of the bed-nets on malaria and overall mortality. In rural Gambia, a 1991 survey revealed that 62% of beds in PHC villages and 51% of beds in non-PHC villages had bednets around them. [10]

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[10] M Aikins and S Bennett, National bednet survey, MRC, The Gambia.

TABLE A: Main cause of death by age of death for the pre-intervention period: Primary Health Care (PHC) and non-Primary Health Care (non-PHC) villages combined.

Cause of death	Age at death (months)								All
	0	1-5	6-11	12-23	24-35	36-47	48-59	60+	
ARI	5	8	8	10	1	3	1	1	37
Malaria	0	2	10	14	18	10	5	11	70
Mening.	1	2	2	2	3	1	0	1	12
Diar/mal	0	1	2	3	4	0	0	0	10
Gastero'	0	4	10	9	0	1	0	1	25
Septaec.	0	2	2	3	0	1	0	0	8
Tetanus	1	0	0	0	0	0	0	0	1
Miscell.	2	1	0	1	2	0	1	1	8
No agree	7	8	8	11	2	3	0	2	46
Unknown	19	5	1	0	1	0	1	1	30
Total	36	37	38	54	37	19	9	17	247

TABLE B: Main cause of death by age of death in the post-intervention period: Primary Health Care (PHC) and non-Primary Health Care (non-PHC) villages combined.

Cause of death	Age at death (months)								All
	0	1-5	6-11	12-23	24-35	36-47	48-59	60+	
ARI	4	11	0	2	2	2	0	0	21
Malaria	0	2	2	5	4	5	2	7	27
Mening.	1	2	3	0	0	0	0	0	6
Diar/mal	0	0	0	1	1	0	0	1	3
Gastero'	0	1	1	1	1	0	0	0	4
Septaec.	0	2	1	0	0	0	0	0	3
Tetanus	0	0	0	0	0	0	0	0	0
Miscell.	3	0	0	0	0	0	0	0	3
No agree	7	8	8	11	2	3	0	2	41
Unknown	19	5	1	0	1	0	1	1	28
Total	34	31	16	20	11	10	3	11	136

TABLE C: Main cause of death by age of death for the pre-intervention period: Primary Health Care (PHC) villages only.

Cause of death	Age at death (months)								All
	0	1-5	6-11	12-23	24-35	36-47	48-59	60+	
ARI	3	4	7	7	1	2	1	1	26
Malaria	0	2	9	11	12	6	5	7	52
Mening.	0	1	1	0	3	0	0	1	6
Diar/mal	0	0	2	3	3	0	0	0	8
Gastero'	0	3	6	7	0	0	0	0	16
Septaec.	0	0	2	2	0	0	0	0	4
Tetanus	1	0	0	0	0	0	0	0	1
Miscell.	2	0	0	1	2	0	0	0	5
No agree	4	3	2	6	5	2	0	1	23
Unknown	9	4	0	1	1	0	1	1	17
Total	19	17	29	38	27	10	7	11	158

TABLE D: Main cause of death by age of death for the pre-intervention period: Non-Primary Health Care (NPHC) villages only.

Cause of death	Age at death (months)								All
	0	1-5	6-11	12-23	24-35	36-47	48-59	60+	
ARI	2	4	1	3	0	1	0	0	11
Malaria	0	0	1	3	6	4	0	4	18
Mening.	1	1	1	2	0	1	0	0	6
Diar/mal	0	1	0	0	1	0	0	0	2
Gastero'	0	1	4	2	0	1	0	1	9
Septaec.	0	2	0	1	0	1	0	0	4
Tetanus	0	0	0	0	0	0	0	0	0
Miscell.	0	1	0	0	0	0	1	1	3
No agree	2	4	2	8	2	2	0	1	21
Unknown	11	0	1	0	0	0	1	1	14
Total	18	15	5	16	6	5	3	7	75

TABLE E: Main cause of death by age of death for the post-intervention period: Primary Health Care (PHC) villages only.

Cause of death	Age at death (months)								All
	0	1-5	6-11	12-23	24-35	36-47	48-59	60+	
ARI	2	5	0	1	1	0	0	0	9
Malaria	0	1	2	0	1	4	0	2	10
Mening.	1	1	1	0	0	0	0	0	3
Diar/mal	0	0	0	0	1	0	0	1	2
Gastero'	0	0	1	0	1	0	0	0	2
Septaec.	0	0	1	0	0	0	0	0	1
Tetanus	0	0	0	0	0	0	0	0	0
Miscell.	0	0	0	0	0	0	0	0	0
No agree	5	4	6	3	0	1	0	1	20
Unknown	8	5	0	0	1	0	0	0	14
Total	17	20	9	16	10	9	2	6	61

TABLE F: Main cause of death by age of death for the post-intervention period: Non-Primary Health Care (NPHC) villages only.

Cause of death	Age at death (months)								All
	0	1-5	6-11	12-23	24-35	36-47	48-59	60+	
ARI	2	4	1	3	0	1	0	0	11
Malaria	0	0	1	3	6	4	0	4	18
Mening.	1	1	1	2	0	1	0	0	6
Diar/mal	0	1	0	0	1	0	0	0	2
Gastero'	0	1	4	2	0	1	0	1	9
Septaec.	0	2	0	1	0	1	0	0	4
Tetanus	0	0	0	0	0	0	0	0	0
Miscell.	0	1	0	0	0	0	1	1	3
No agree	5	7	1	5	3	1	1	0	23
Unknown	9	3	1	0	0	0	0	0	13
Total	18	15	5	16	6	5	3	7	89

November 1991

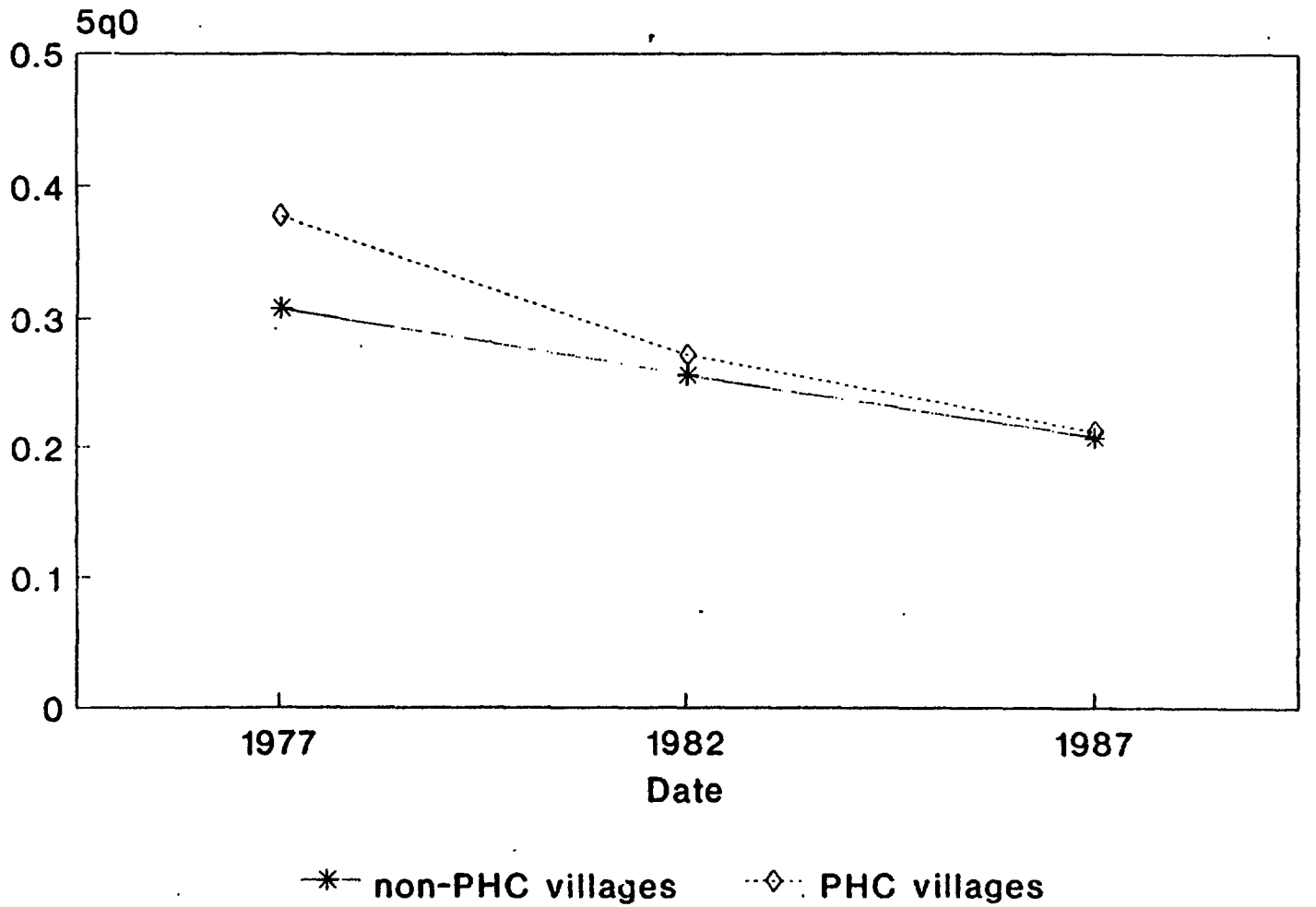
Under 5 mortality
5q0
0.5
0.4
0.3
0.2
0.1
0
1977
1982
1987
Date
non-PHC villages
PHC villages

Figure 1

Main causes of death for all under 5's before and after the use of bed-nets

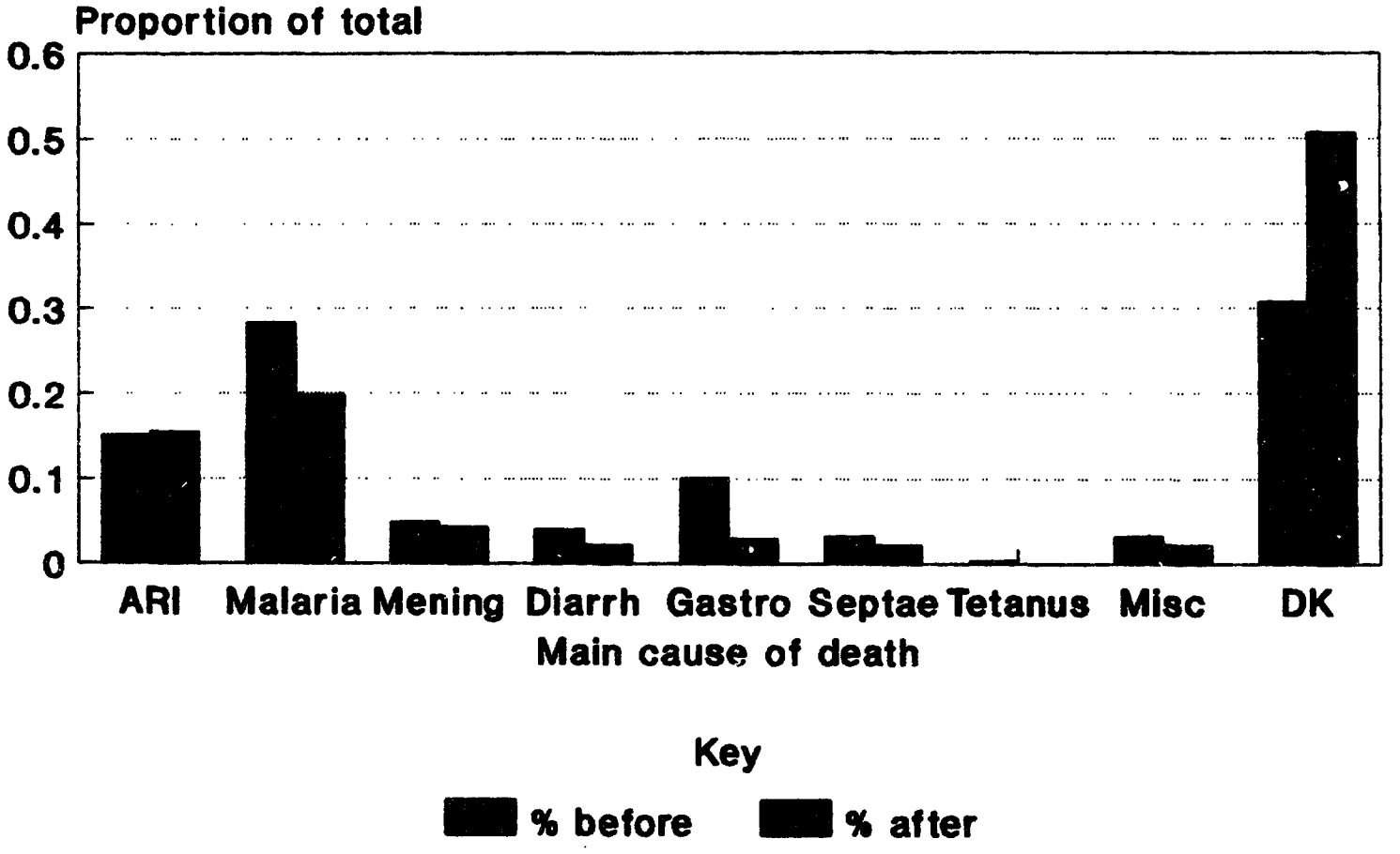

Figure 2

Numbers of deaths by main cause in non-PHC villages before and after the use of bed-nets

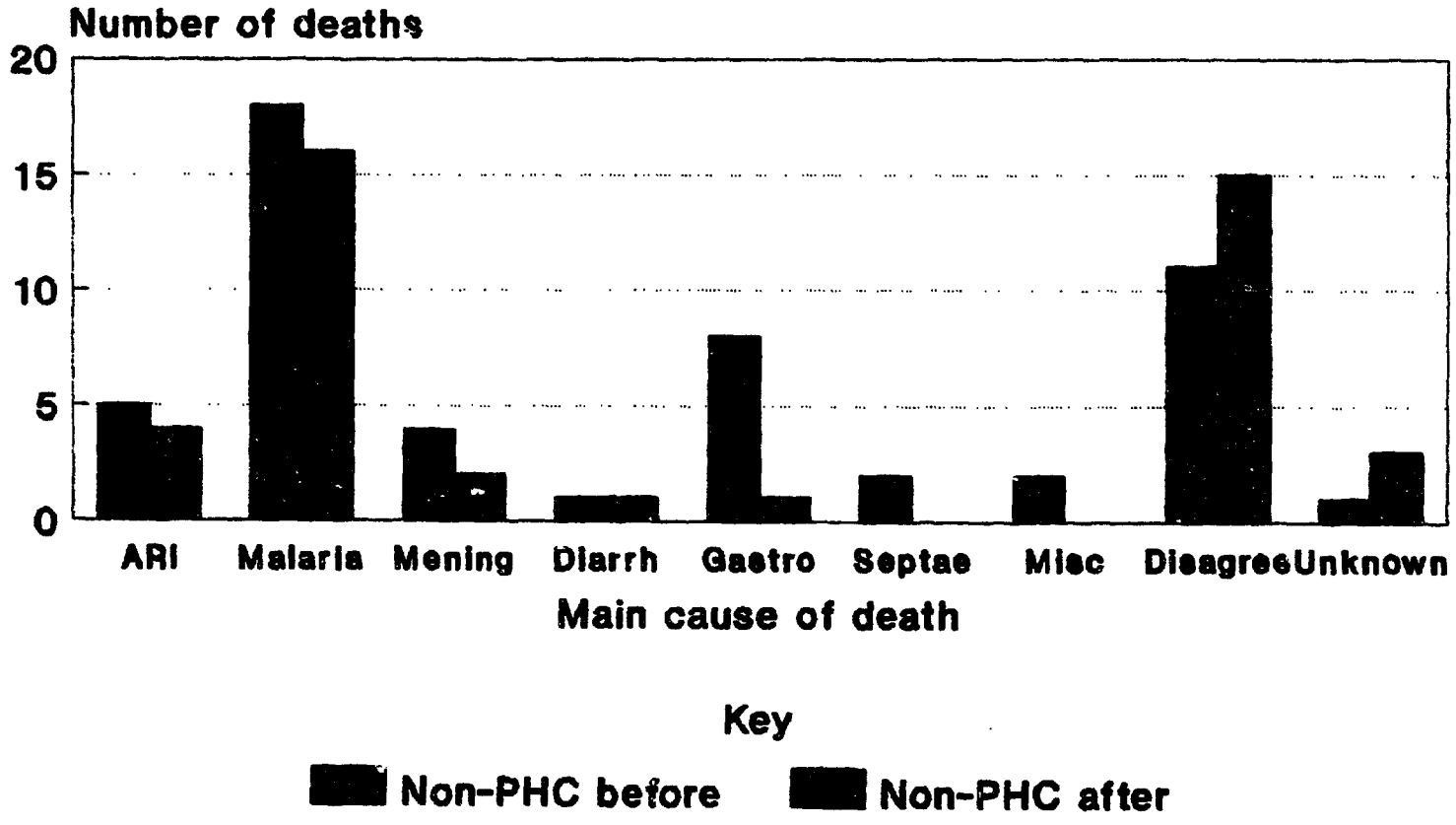

Figure 3

Numbers of deaths by main cause in PHC villages before and after using bed-nets

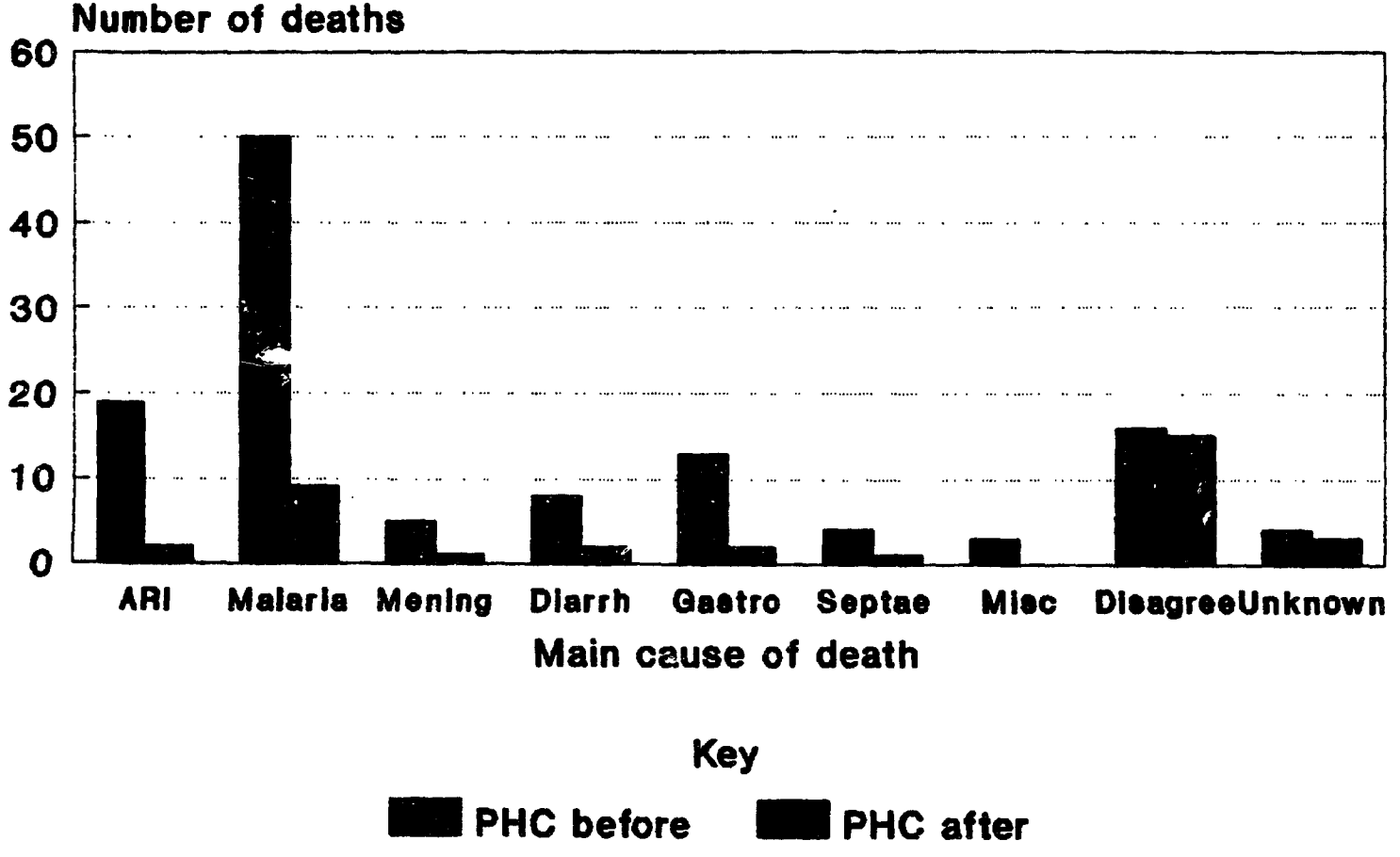

Figure 4

Ratios of numbers of deaths by cause in PHC and non-PHC villages before and after the use of bed-nets

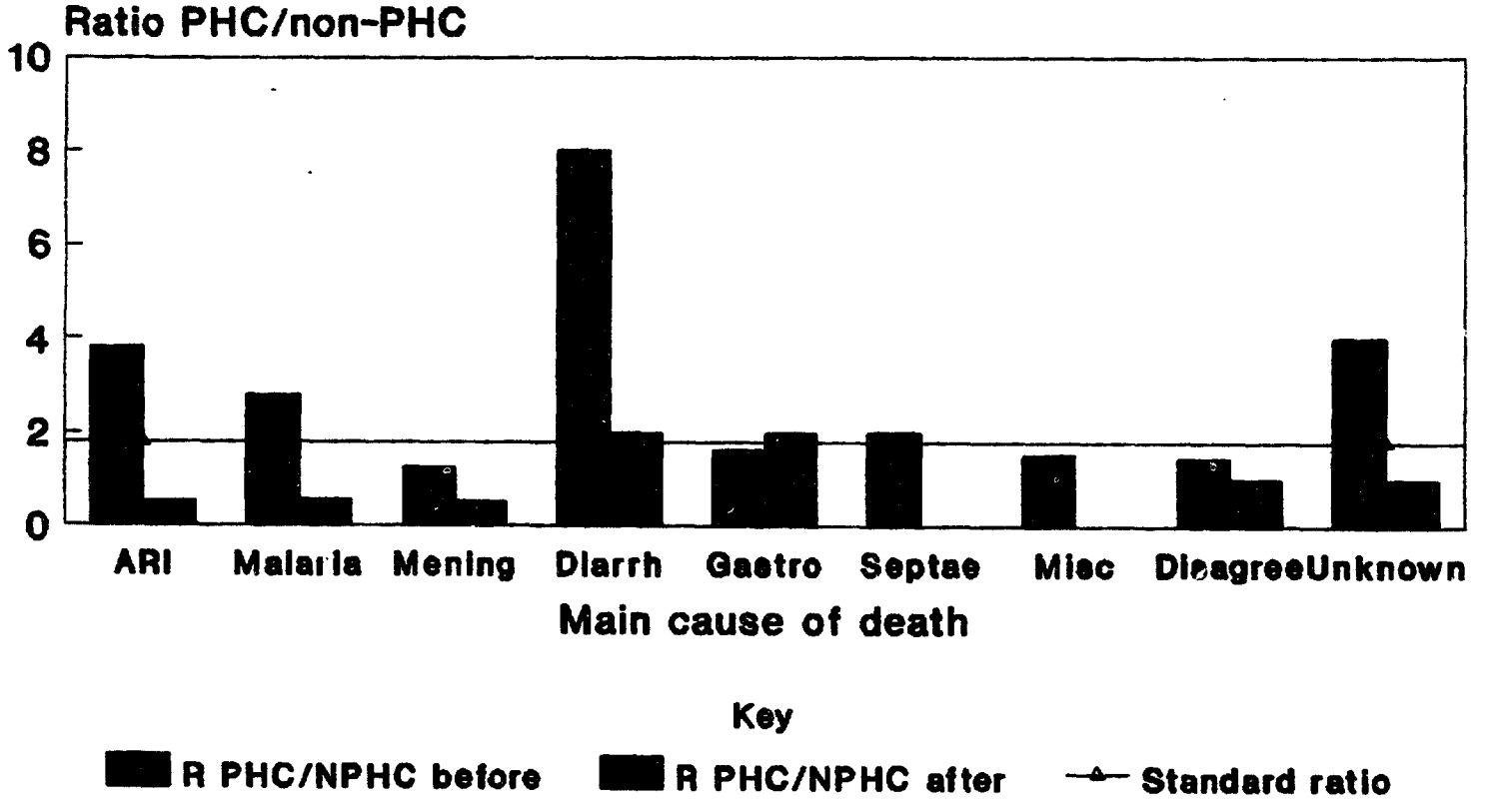

Figure 5

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